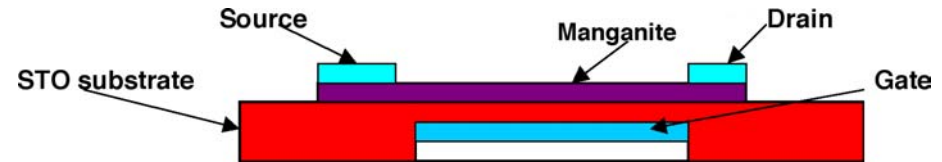


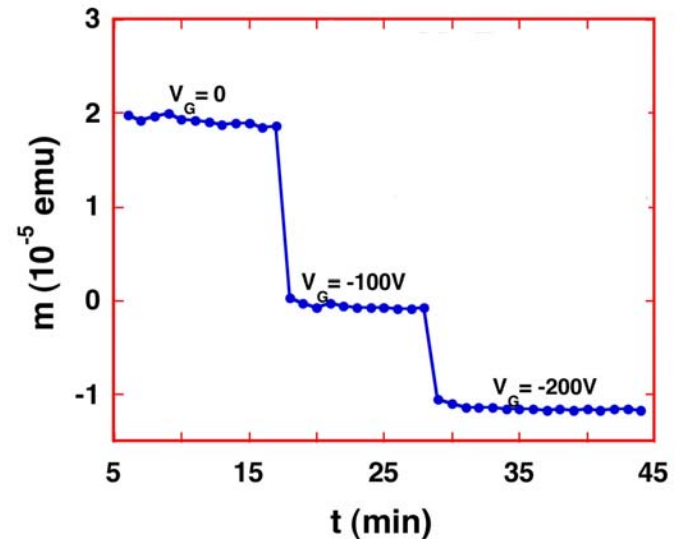
# Tuning the Magnetic Moment of a Ferromagnet by Electrostatic Gating

A. M. Goldman, University of Minnesota, DMR-0138209

We have been studying the response of ultra-thin films of lanthanum calcium manganite to electrostatic fields in a field effect transistor geometry. The response to electric and magnetic fields resembles that of glasses and suggests that charge, spin and strain are connected in a complex manner. We have exploited this and have been able to tune the magnetization of an ultrathin film of  $La_{0.8}Ca_{0.2}MnO_3$  by the application of an electrostatic field through a gate. The key to doing this has been the development of micro-machined and surface treated single crystal strontium titanate that can double as a substrate and a gate dielectric.



Cartoon of micro-machined substrate with manganite film and gate. The part of the substrate between the gate and the manganite film can be as thin as 10  $\mu\text{m}$ .



Gate induced change of magnetic moment of a film. A magnetic field of -450 Oe was applied at time  $t = 0$  after saturating the magnetization with a 5000 Oe field. The various values of the gate voltage  $V_G$  are indicated.

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*cond-mat/0407607, submitted to Physical Review Letters.*

We have developed a technique that permits the properties of thin film materials to be altered electrically. The films are grown on a single-crystal wafer of strontium titanate (STO) that is both a good substrate for growing thin films and a good insulator. By thinning the STO single crystals and putting an electrode on the back side, one can control the number of charges in the film grown on top of the STO by changing the voltage applied across the insulating STO. This is effectively the same configuration as in silicon field effect transistors found in most electronics, but made with very different materials. Our goal in this work was to produce a platform with which we could investigate the electrical control of superconductors. At the time we developed the platform, we tested it using films of lanthanum calcium manganite (LCMO), which happened to be available to us. This compound is one of several that exhibit the phenomenon of colossal magnetoresistance (CMR). In CMR compounds, resistance can change by many orders of magnitude upon the application of sufficiently large magnetic fields. The CMR compounds have been of interest because of their potential use as memory and logic elements. A surprising and very interesting result is that we have been able to change the magnetic moment of a CMR film by applying a voltage to the back of the thinned STO crystal on which the CMR film is grown. Usually, applied magnetic fields affect the magnetic properties of materials, and applied electric fields affect the electrical properties. However, here we find that an applied electrical field, produced by the application of the voltage across the STO, impacts the magnetic properties of the material due to the complex cross-coupling of electric, magnetic and structural degrees of freedom in these materials. This provides the potential basis for developing an important nonvolatile memory element for technology applications. Of course much work would be needed to develop a useful device, as materials exhibiting this property at room temperature would have to be found and a way of producing many devices on a single wafer would also have to be developed.

This work is not part of the main thrust of our program, but was a scientific opportunity, which developed when we needed to carry out a quick test of the strontium titanate structures. These structures will ultimately be used to tune the properties of superconductors.

# Tuning the Magnetization of a Ferromagnet by Electrostatic Gating

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## Education:

This work involved a graduate student, Melissa Eblen-Zayas, a postdoctoral associate, Dr. Anand Bhattacharya, and an undergraduate Neal Staley. Ms. Eblen-Zayas was an NSF pre-doctoral fellow and now holds a University of Minnesota Graduate Dissertation Fellowship. Dr. Bhattacharya is now at Argonne National Laboratory, and Mr. Staley is now a first year graduate student at Penn State University. The technique for thinning single crystal strontium titanate substrates was developed by Mr. Staley.

## Societal Impact:

Devices in which the magnetization of a film is altered electrostatically could serve as building blocks for a future nonvolatile memory technology. In effect the structures we have made are nonvolatile memory elements. Of course significantly more materials research and development would be needed to bring this about.